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EFFECT OF DEPTH OF LIQUID ON DAMPING OF A QUARTZ OSCILLATOR

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Plate III

ABSTRACT. The paper describes the results obtained in the investigations of damping of high frequency sound waves at different depths of liquids. The result obtained for these liquids suggests that there is no definite dependence of the damping effect either on the hydrostatic pressure of the liquid or viscosity, but it is found to have closer agreement with the order of the absorption values recently determined by others.

INTRODUCTION

Measurements made at a high frequency of several millions per second in liquid show damping. Damping produces (1) a change in the frequency and (2) a lowering of the amplitude.

Parthasarathy[1] has detected a change of frequency of a quartz oscillator in liquids due to damping. This change in frequency with depth may be attributed to the hydrostatic pressure of the liquid, viscosity or the absorption of the sound waves.

The experiments of Lucas[2] and Biquard[3] in absorption showed serious disagreement with the classical theory, according to which the absorption is entirely due to viscosity and thermal conductivity. Recently E. G. Richardson,[4] by using a hot wire detector in a few liquids has shown that though the absorption values were higher than those required by the classical theory, they were very much lower than those obtained by Claeys[5] and others The serious difference is that while Claeys has shown the value of CS_2 to be 2000 times that of its calculated one, Richardson has shown it to be only about 4 times greater An attempt is made in this paper to examine the dependence of damping on the density and viscosity of a few liquids which show considerable absorption of ultrasonic waves.

EXPERIMENTAL ARRANGEMENT

A single valve oscillator circuit of Hartley type was employed. The quartz crystal used was an x-cut of dimension 20 × 20 × 2 mm. The frequency of the oscillation was about 4.3 m c., *i.e.*, the third harmonic of the crystal. The quartz crystal was held between two metal contacts.

The container used was a tall rectangular vessel one foot in height and 2″ × 2″ in sectional area. The vessel was placed on a rising table with a fine screw arrangement by which it was possible to raise the table gradually and the stem of which was graduated in mms. to denote the distance through which the vessel has been raised. The quartz crystal was mounted on an independent stand.

The frequency of the oscillator was measured at different depths with a precision wavemeter of the General Radio Co. A suitable optical system was set up to get the diffraction spectra at different depths on a photographic plate. A constant wave-length of light of mercury spectrum isolated by a wratten filter No. 77 was used.

EXPERIMENTAL PRECAUTIONS

It is important to check that there is no fluctuation in the frequency at the same depth. The H. T. and L. T. voltages should be maintained without variation during the time of measurement. Care was taken to prevent evaporation which would cause a change in the level of the liquid.

A constant distance of 1.50 cm. between the base of the crystal and the beam of light was maintained when the diffraction photographs at varying depths were taken. The quartz crystal was kept undisturbed throughout the investigation. The liquids used were all pure and redistilled.

RESULTS

The damping coefficient k can be calculated from the usual formula

$$k = \sqrt{n^2 - n_1^2}$$

where n is the undamped frequency and n_1 the damped frequency. Table I gives the frequency at different depths and the corresponding coefficient of damping.

TABLE I

Damping Co-efficient

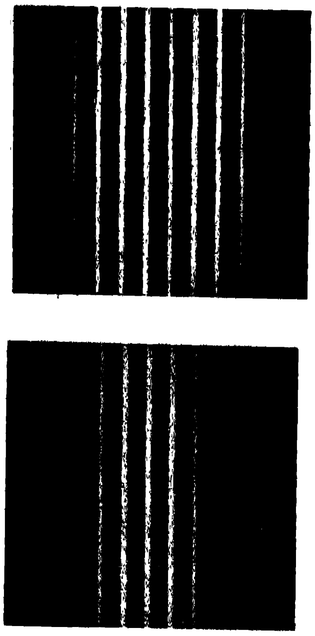
Depth of incident beam from liquid level *	Benzene		Xylol		Carbon Tetrachloride		Carbon Bisulphide	
	Frequency in m.c.	Damping Coefficient	Frequency in m.c.	Damping Coefficient	Frequency in m.c.	Damping Coefficient	Frequency in m.c.	Damping Coefficient
1.5 cm.	4.3381	Standard	4.2401	Standard	4.2053	Standard	4.2959	Standard
2.5 cm	4.3034	0.5491 × 10^6	4.2100	0.5000 × 10	4.2248	0.5917 × 10^6.	4.2491	0.6403 × 10^6
3.5 cm.	4.2959	0.6001 × ,,	4.2066	0.5917 × ,,	4.2168	0.5403 × ,,	5.2375	0.7142 × ,,
4.0 cm.	4.2896	0.6403 × ,,	4.2058	0.6682 × ,,	4.2011	0.7416 × ,,	4.2306	0.7551 × ,,
5.5 cm.	4.2774	0.7211 × ,,	4.1673	0.8307 × ,,	4.1641	0.9219 × ,,	4.2162	0.8307 × ,,
7.5 cm	4.2030	0.8000 × ,,	4.1538	0.8945 × ,,	4.1527	0.9747 × ,,	4.1722	1.0290 × ,,
8.0 cm.	4.2595	0.8307 × ,,	4.1495	0.9164 × ,,	4.1500	0.9849 × ,,	4.1700	1.0350 × ,,
8.5 cm.	4.2572	0.8368 × ,,	4.1411	0.9383 × ,,	4.1479	0.9949 × ,,	4.1662	1.0490 × ,,

* The depth of the crystal will be 1.50 cms. less than the values shown in this column.

Depth

4·0 cms

8·5 cms

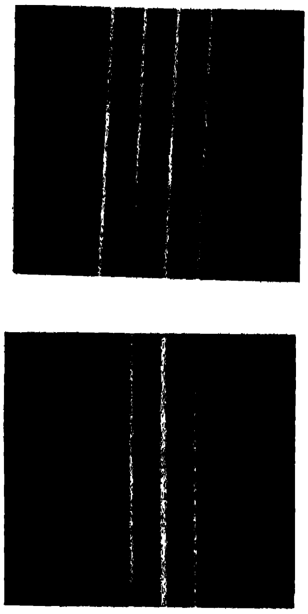


BENZENE

Depth

1·5 cms

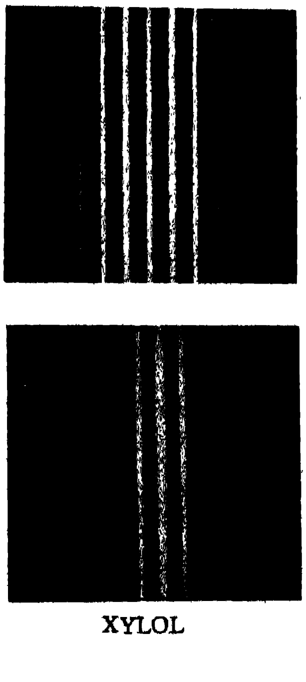
8·5 cms



ccl_4

1·5 cms

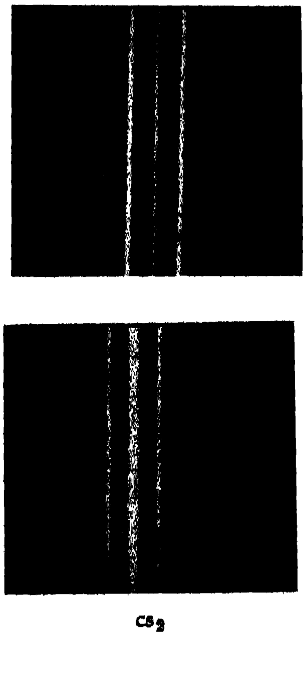
8·5 cms



XYLOL

1·5 cms

8·5 cms



cs_2

The frequency of the oscillator when the crystal was just immersed in the liquid was taken as the standard in each case. It is evident from the table that the damping is considerable at a depth of about 8.0 cms. for all the liquids investigated.

TABLE II

Liquid	Damped frequency of the crystal at a depth of 6.5 cms.	Density (Hand-Book of Chemistry and Physics)	Viscosity (Hand-Book of Ch. and Ph.)
Benzene	0.0786 m.c. = 1.8%	0.8784 at 20°C.	0.00649 at 20°C.
Xylol	0.0996 „ = 2.3%	0.8641 „	0.00615 „
CCl_4	0.1153 „ = 2.7%	1.5950 „	0.00969 „
CS_2	0.1259 „ = 2.9%	1.2628 „	0.00367 „

Table II gives the percentage damping of frequency in each liquid at a constant depth of 8.0 cms. of the beam of light from the surface of the liquid or 6.5 cms. of the crystal from the surface.

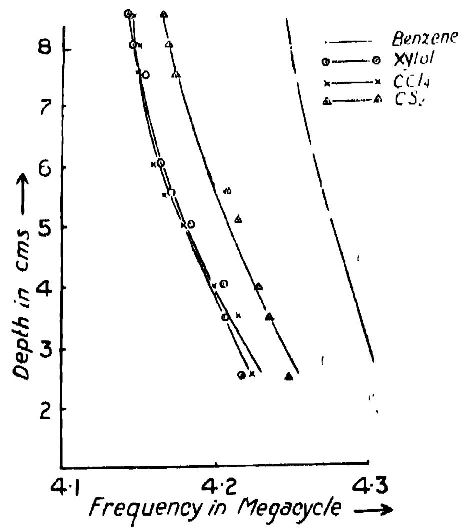


FIG. 1

Fig. 1 shows the relation between the depth of the crystal, rather the beam of light, below the surface of the liquid and the corresponding frequency of oscillation. The experimental points for all liquids are in straight lines. Near the bottom (where $d > 6$ cms.) there is a slight deviation.

DISCUSSION

The energy of the oscillation is lost through the crystal holders and by damping of the liquid. Now, if this damping effect is due to the hydrostatic pressure $h\rho g$ of the liquid, then it must depend on the density of the liquid. But from table II it is seen that the damped frequencies do not increase with the liquids of higher density. It is also seen that there is no increase of damped frequencies with viscosity. It is observed that the change in the magnitude of the damping effect in the liquids investigated follows more closely the order of their absorption values of ultrasonic waves in them.

The photographs also depict the decrease of orders with depth, which suggests that the supersonic intensity decreases with the increase of damping.

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